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Report No. CG-D-36-80

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COMMUNICATIONS REQUIREMENTS

FOR A

LORAN-C POSITION MONITORING SYSTEM

FOR

VTS VALDEZ ALASKA

LT T. M. DROWN

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16. Abstract

The Coast Guard is investigating alternative means to provide increased surveillance capability in its Vessel Traffic Service (VTS) at Valdez, Alaska. The requirement is to extend active position monitoring of ships throughout Prince William Sound. One method of surveillance is to transmit Loran-C time differences from each ship to VTS Valdez for display and storage. This document defines the requirements for a Loran-C position monitoring system using the existing VHF-FM communication network.

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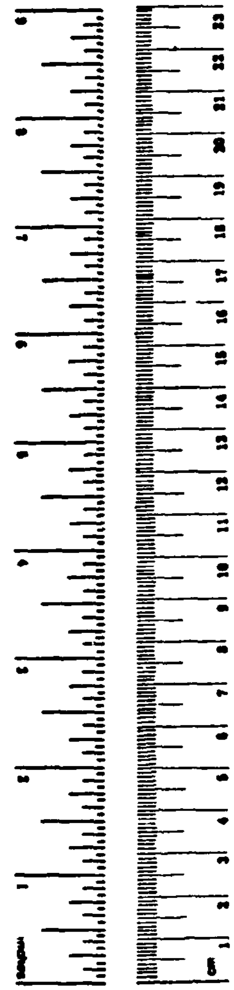
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

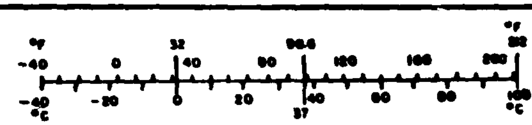


TABLE OF CONTENTS

1.0 INTRODUCTION..........1

1.1 Purpose..........1
1.2 Background..........1

2.0 DESCRIPTION OF SERVICE AREA..........3
2.1 Topography..........3
2.2 Operations..........3
2.3 Communications..........5
2.4 Future Growth..........8
2.5 References..........

3.0 POSITION MONITORING SYSTEM CONCEPT..........9

3.1 Overview..........9
3.2 Operational Objectives..........9
3.3 Basic Communications..........9
3.4 System Concept..........11

4.0 ANALYSIS OF IMPLEMENTATION ALTERNATIVES..........11

4.1 Modulation..........11
4.2 Message Structure..........14
4.3 Polling Techniques..........16
4.4 Bit Rate..........18
4.5 Signaling Tones..........18
4.6 Carrier Deviation..........19
4.7 Summary of Technical Characteristics..........19

5.0 DESCRIPTION OF AN OPERATIONAL SYSTEM..........20

5.1 Polled Loran-C Display System (PLDS) Communications..........20
5.2 PLDS Communications Protocol..........23
5.3 Message Error Handling..........26

6.0 SUMMARY AND RECOMMENDATIONS..........26

6.1 Communications Reliability..........26
6.2 Variations of the Operating Concept..........28

APPENDIX A

A.1 Radio Transmitter and Receiver..........A-1
A.2 Signaling Characteristics..........A-1
A.3 Data Code..........A-1
A.4 Communications Protocol..........A-1
A.5 Message Format..........A-2
A.6 Time Characteristic of Each Transmission..........A-6
A.7 Ship and Shore Station Identification..........A-7

LIST OF FIGURES AND TABLES

Figure 1	VTS Service Area	2
Figure 2	VHF-FM and Radar Coverage	4
Figure 3	High Level Sites	6
Table 1	Site Characteristics	7
Figure 4	Coverage Area	10
Figure 5	System Concept	12
Figure 6	Message Format	22
Figure 7	Timing Cycle	24
Figure 8	Data Loss Graph	29
Figure A-1	General MSG Format	A-3
Figure A-2	Timing Relationships	A-7

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1.0 INTRODUCTION

1.1 Purpose

This report provides a detailed discussion of the communications requirements for a Loran-C based surveillance system proposed for the Prince William Sound Vessel Traffic Service. The positions of tankers which call at Valdez, Alaska to load crude oil from the Trans-Alaskan Pipeline (TAPS) are currently monitored by a Vessel Movement Reporting System (VMRS). The VMRS requires that each vessel report its position via a voice radio call at designated points during its transit through Prince William Sound. A need to monitor the position of the TAPS tankers as they transit Prince William Sound more accurately than is possible with a VRMS has been identified. Additionally, there is a potential requirement to monitor the position of other vessels in Prince William Sound of a size similar to the tankers, if economic growth occurs in Valdez.

After a description of the operational environment in Prince William Sound, the project phases which culminated in the implementation of a useable communications subsystem for a Loran-C based position monitoring scheme are discussed. The rationale used to select some of the operating parameters of the subsystem is discussed. Appendix A contains a set of recommended subsystem parameters that were developed from the prototype development and evaluation.

1.2 Background

The southern terminus of the Trans-Alaskan Pipeline is the Alyeska Marine Terminal located on the bay of Port Valdez, AK. Oil carrying ships arrive at the terminal almost daily to load crude oil for shipment to the continental U.S. Authorization to construct the pipeline was granted in the Trans-Alaskan Pipeline Authorization Act (P.L. 93-153), passed November 1973. The act also contained specific requirements for the U.S. Coast Guard to establish a Vessel Traffice Service (VTS) to prevent loss of life and property and to protect the navigable waters surrounding Valdez and their resources from environmental damage. The VTS service area coverage was designated to include the waters of Port Valdez, Valdez Narrows, Valdez Arm and Prince William Sound. Figure 1 shows the VTS service area.

The Prince William Sound Vessel Traffic Service, more popularly called VTS Valdez, has been operational since 25 July 1977. Prior to putting the Prince William Sound Vessel Traffic Service in operation, the Coast Guard published a notice of proposed Federal rule making which contained a description of the surveillance techniques to be used. Several responses from both public and private interests in Alaska emphatically supported more surveillance than proposed for the southern Prince William Sound area. The comments favored more active tracking of the oil tankers transiting the sound. The TAPS oil tankers are already required to carry Loran-C equipment, therefore, the development of a Loran-C based position monitoring system has been emphasized.

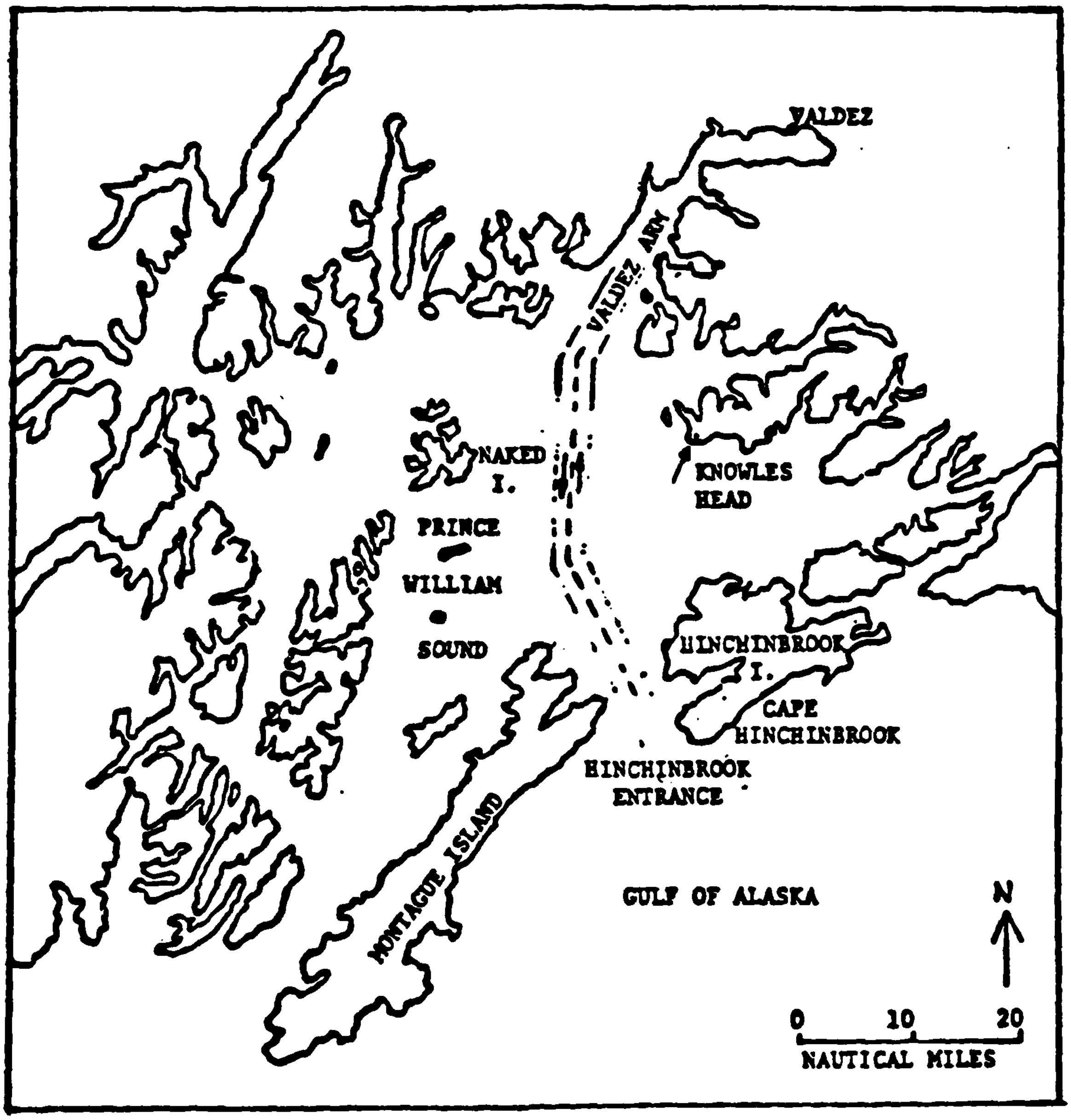


Figure 1 VTS SERVICE AREA

2.0 DESCRIPTION OF SERVICE AREA

2.1 Topography

The terrain surrounding the Valdez/Prince William Sound Area is extremely rugged. Valdez is in a fiord-like setting with 2500 foot ridges lining Valdez Arm, Valdez Narrows and Port Valdez. In addition, both the mainland and the islands surrounding Prince William Sound contain mountains of 1000 to 2000 foot heights. This topography complicates the effective use of the two most widely used VTS operating tools, radar and VHF-FM communications, which are line-of-sight RF transmission systems. As a result, both remote radar and remote VHF-FM transmit/receive sites must be used. These sites are tied to the VTS operations center by microwave link. Figure 2 shows the area covered by the two systems.

2.2 Operations

The authority for the Coast Guard to operate the Prince William Sound Vessel Traffic Service is contained in the Ports and Waterway Safety Act of 1972. The regulations governing the operations are published in Title 33, Code of Federal Regulations, Subchapter P, Part 161. An operating manual, "Vessel Traffic Service Prince William Sound Operating Manual" (CG-D17-010) dated July 1977, which contains excerpts of the regulations with clarifying comments, is available to mariners from VTS Valdez.

VTS, Valdez is operated on a 24-hour-a-day, 7-days-a-week basis. The operations center, called the Vessel Traffic Center (VTC), is located in the Coast Guard Marine Safety Office in the town of Valdez, AK. From the VTC, all vessel traffic in both Prince William Sound and in the Valdez area is continually monitored. Advisories are issued to promote safe traffic movement. A vessel's size, its use and its location in the service area determines its level of monitoring. Within the Vessel Traffic Center, two distinct Coast Guard mission functions are performed:

(a) VTS Valdez - which monitors vessel traffic.

(b) Radio Valdez - which receives and relays Coast Guard record message traffic via radio and landline teletype, files float plans for boaters and handles any SAR cases that occur in Prince William Sound. In addition, radio Valdez transmits local Notices to Mariners on a regular basis.

There are normally two watchstanders on duty in the VTC at all times. One watchstander is assigned to perform the VTS monitoring duties; the other is assigned as a communications watchstander. Both are cross-trained to provide assistance to one another when necessary. The VTS watchstander is called the controller; the other watchstander is designated radioman. As many as eighty-five telephone calls per day are answered by the two watchstanders.

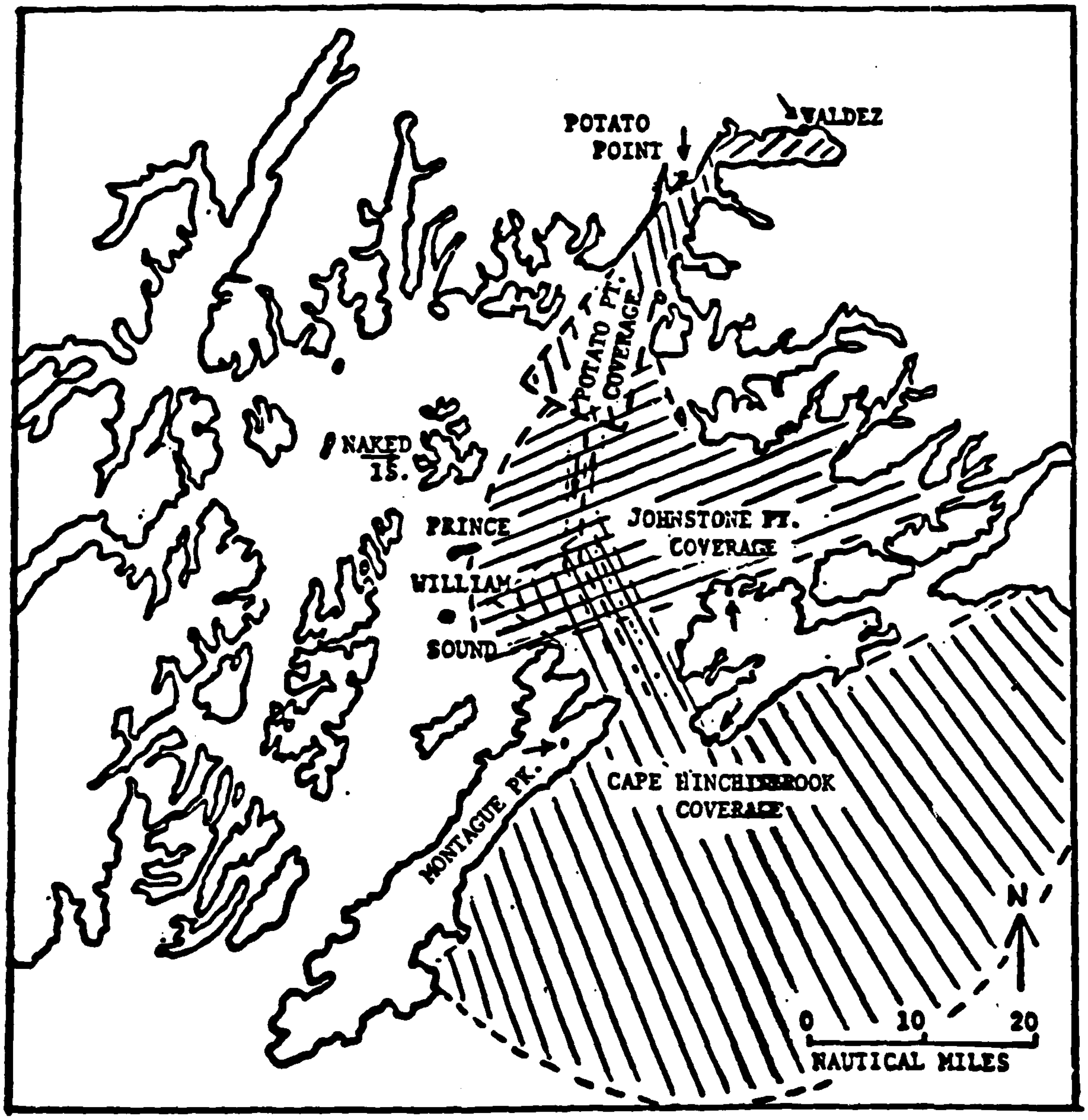


FIGURE 2 ESTIMATED VHF-FM COVERAGE

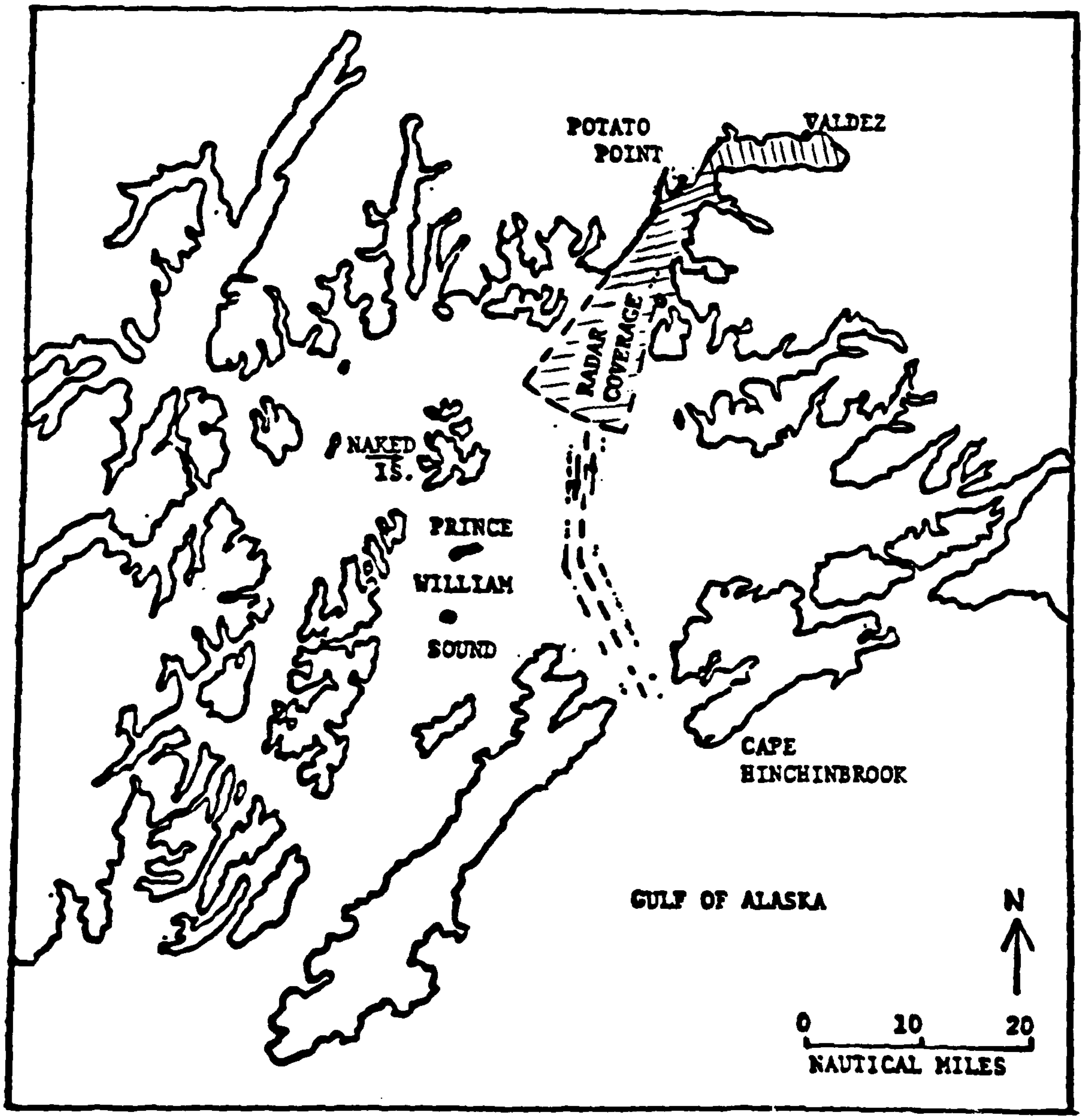


FIGURE 2a RADAR COVERAGE AREA

The controller can monitor vessel traffic by radar and the Vessel Movement Reporting System (VMRS). Radar provides continuous coverage from a point north of Naked Island (see Figure 2) into Port Valdez. When an oil tanker is transiting within the radar coverage area, the controller is required to maintain a plot of the tanker's position. Position plots are made every six minutes. A complete radar plot requires 35-40 fixes: each position plot takes approximately thirty seconds. The VMRS is a cooperative monitoring scheme in which vessels provide position, course and speed information to the VTC via VHF-FM CH 13. When transiting Prince William Sound each tanker is required to report at two locations, abeam of Schooner Rock at Hinchinbrook Entrance and abeam of Naked Island. A vessel is under VMRS monitoring for approximately five hours. In addition to making the two VMRS reports in Prince William Sound, tankers are required to make preliminary reports both twenty-four hours and three hours prior to arriving at Hinchinbrook entrance and at least thirty minutes prior to either entering or beginning to navigate in the VTS service area. When transiting Prince William Sound, all traffic is required to follow a traffic separation scheme (TSS). The TSS route is shown in Figure 1.

An anchorage is being established just south of Knowles Head (Figure 1).

2.3 Communications

Figure 3 shows the location and coverage area for the five VHF-FM transmit/receive sites located at Valdez, Potato Point, Johnstone Point, Cape Hinchinbrook and Montague Peak. Table 1 lists some of the characteristics of each site. Each site has the same basic equipment configuration of:

(a) Redundant Transmit/Receive Equipment
(b) Selectable Transmit Power - Fifty or Ten Watts
(c) Guard Receivers on CH 13 and CH 16
(d) Six channel transceiver

Montague Peak operates on only ten watts and at a low duty cycle to conserve the thermal generating units which provide primary power. Johnstone Point has no guard receivers.

Four of the sites are remotely linked to the operations center by a Cardion Microwave System. This system provides thirty-six voice grade channels (300Hz to 3400Hz). Twelve of the channels are used for Moore Alarm Systems which are installed at the remote sites, and seventeen channels are used to carry transmit and receive audio to and from the remote sites.

The two microwave relay stations are located at Montague Peak and Mount Thomas (adjacent to Potato Point). The Montague Peak station relays through the Mount Thomas station to the VTC. The Montague Peak station directly serves the Montague Peak, Johnstone Point and Cape Hinchinbrook VHF-FM sites. The Mount Thomas station directly serves the Potato Point VHF-FM site.

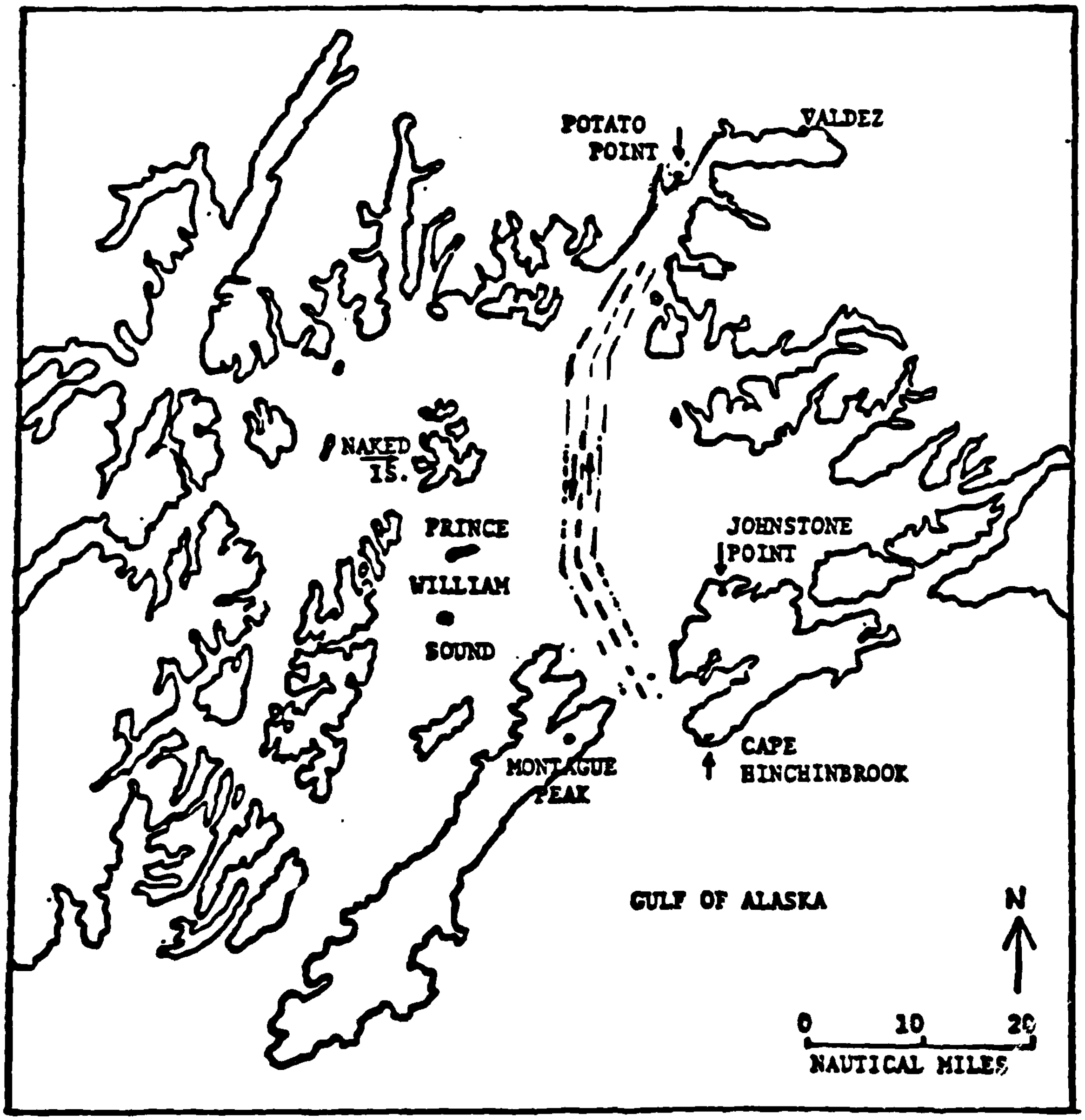


FIGURE 3 VHF-FM HIGH LEVEL SITE LOCATIONS

	VALDEZ	POTATO POINT	JOHNSTONE POINT	CAPE HINCHINBROOK	MONTAGUE PEAK
POSITION	61-08N 146-21W	61-03N 146-41W	60-29N 148-36W	60-15N 146-39W	60-15N 147-00W
CHANNELS	6,13,16 21,22,81	6,13,16 21,22,81	6,13,16 21,22,81	6,13,16 21,22,81	6,13,16 21,22,81
MAXIMUM TRANSMIT POWER	25 WATTS	50 WATTS	50 WATTS	50 WATTS	10 WATTS
ANTENNA TYPE	ARRAY	ARRAY	ARRAY	ARRAY	WHIP
ANTENNA GAIN	6dB	9dB	9dB	9dB	0dB
DIRECTION MAXIMUM GAIN	035°T	210°T	320°T	140°T	OMNI-DIRECTIONAL
TERRAIN HEIGHT	50ft	75ft	20ft	250ft	2240ft
ANTENNA HEIGHT (ABOVE TERR.)	35ft	90ft	100ft	75ft	30ft
LINE OF SIGHT TO WATER	12.2nm	18.2nm	15.5nm	25.5nm	67.4nm
TO ANT. 30 ft. ABOVE WATER	20.0nm	25.9nm	23.2nm	33.2nm	75.1nm

Table 1 VHF-FM SITE DATA

The VTS controller and the radioman each has his own console. Each position provides the capability to either independently control the transceiver equipment at each site, control any combination of sites or control all five sites simultaneously. Each console has five speakers, one speaker for each site. Any one of the three receivers (two guard receivers and one transceiver) located at one site can only be monitored through one speaker on the console by a system of muting two receivers while one is active. The muting scheme is not entirely effective, and this causes ocassional feed through and/or crosstalk at each console.

Through operating experience, the established procedures for carrying out communications are:

(a) Potato Point, Montague Peak and Cape Hinchinbrook are used for VTS on CH 13.
(b) Johnstone Point is used on CH 16 and CH 22 for SAR and Notice to Mariner Broadcasts.
(c) Valdez is used for communications in Port Valdez and, occasionally, for communications in the area of Hinchinbrook Entrance. Communications to the Hinchinbrook Entrance appear to take advantage of an RF skip phenomenon.

The common practice is to listen to either CH 13 or CH 16 using the guard receivers and only use the transceiver to carry out two-way communications. However, because Johnstone Point doesn't have any guard receivers, it's transceivers must be dedicated to CH 16 to listen for SAR calls.

A third communications position in the operations room provides a spare for the watchstanders.

2.4 Future Growth

To date, the average volume of traffic is nine vessel transits per day. Of the nine transits, four are tanker transits. This means that, on the average, two tankers call at Valdez each day. The Alyeska terminal is capable of accommodating four tankers at a time. Therefore, it is possible that a worst case situation could occur whereby four tankers are leaving Valdez, four tankers are at anchor in the vicinity of Knowles Head waiting their turn to load and four tankers are arriving to go to anchor at Knowles Head. All twelve tankers would have to be monitored as they moved through Prince William Sound.

In addition, plans for Valdez port expansion include the construction of a container port and an oil refinery by 1985. Estimates are that this would add a maximum of two container ships and four refinery product carriers to the traffic volume each day. These six ships would probably be included in the proposed surveillance scheme. This makes an estimated worst case total of eighteen ships to be tracked at one time.

3.0 POSITION MONITORING SYSTEM CONCEPT

3.1 Overview

The proposed system is to provide a complete record of a vessel's position as it proceeds along the lanes of the established Traffic Separation Scheme in its transit of Prince William Sound. The present area of operation extends through the Sound from Hinchinbrook Entrance to the southern limit of radar coverage which is in the vicinity of Naked Island. Figure 4 shows the area to be covered.

3.2 Operational Objectives

The objectives for the Position Monitoring System are to provide positioning accuracies comparable to those allowed by the Loran-C signal conditions in Prince William Sound, and provide position information with the same regularity as required of a radar position plot, i.e. once every six minutes. In addition, there should be little or no increase in the workload presently performed by the VTS watchstander. Also, communications should be carried out over existing communications links.

3.3 Basic Communications Subsystem Constraints

The subsystem development was constrained by several practical considerations:

(a) Method of Operation

The existing VMRS requires that a vessel communicate with the VTC: when abeam of Schooner Rock in Hinchinbrook Entrance and when abeam of Naked Island. The transit between these two points can take up to three hours. If the proposed system is to provide a position report every six minutes between these points, the number of reports increases to approximately thirty. The increased burden placed on both the VTC watchstander and a vessel operator, if this function is performed manually, would be unacceptable. A form of automation is considered mandatory.

(b) Information Passed

The minimum information required at the VTC is vessel identification, vessel position and the time of position observation. This information must be updated at least every six minutes.

(c) Communications Frequency

Communications are to be carried out using existing maritime mobile communications equipment.

(d) Flexibility

The proposed system must be able to communicate with a minimum of eighteen vessels in one six minute period. This will accommodate the

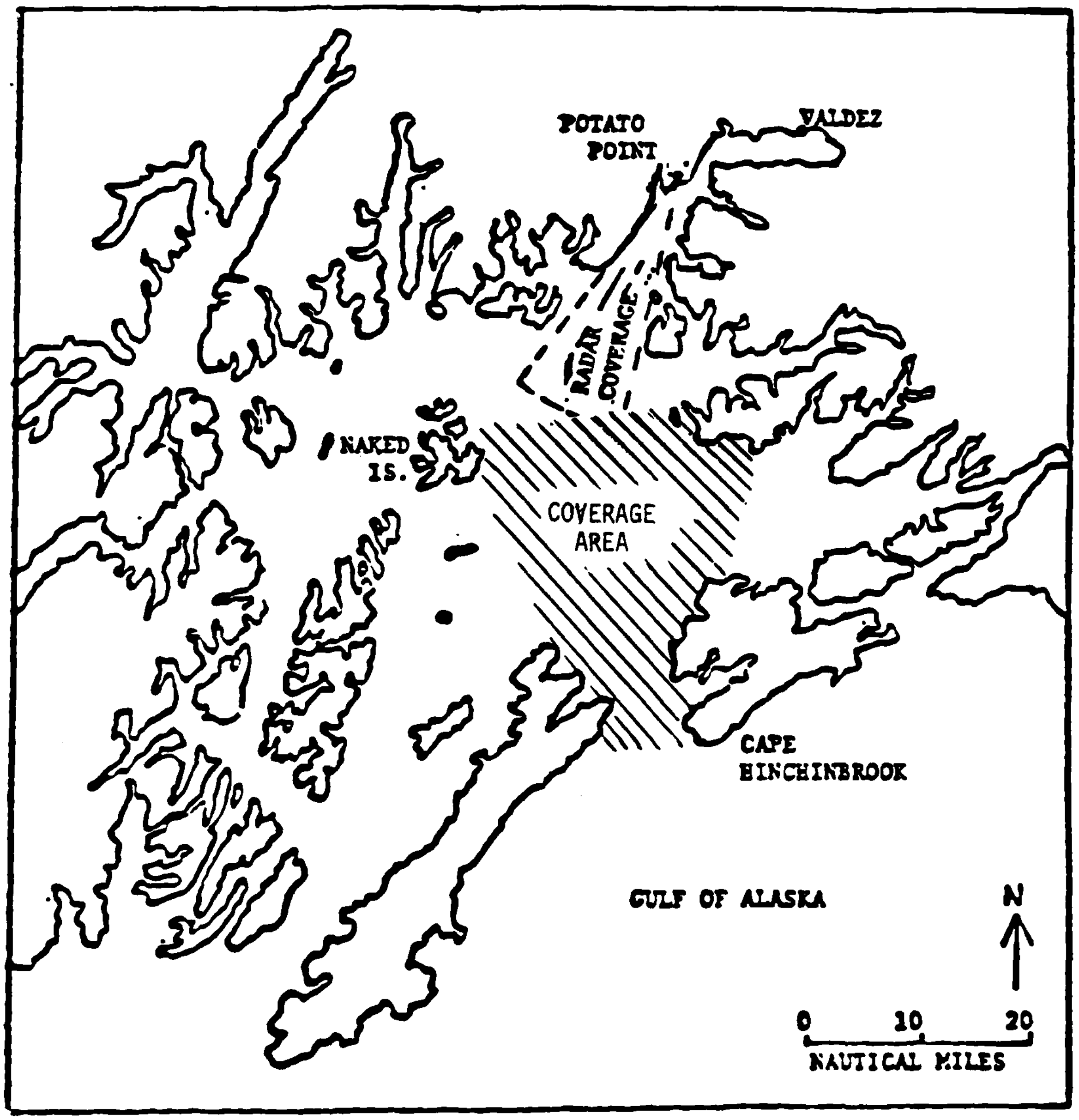


FIGURE 4 AREA OF ADDITIONAL SURVEILLANCE

worst case situation postulated in Section 2.4. However, it is not clear that all vessels being monitored under the worst case situation will have Loran-C equipment. Some might have other navigation equipment that provides latitude/longitude readout. Therefore, the system must be flexible enough to accommodate both latitude/longitude data and Loran-C time difference data.

(e) Communication Range

Reliable communications must be maintained between the VTC and vessels operating in the area of Prince William Sound between Hinchinbrook Entrance, Naked Island and Knowles Head. A figure of merit to better define the term "reliable" has not been developed. An initial goal of achieving a 95% probability that reports of current position will be received from a vessel at intervals that are not greater than six minutes apart has been arbitrarily set.

3.4 System Concept

The present system concept is to provide for automatic communications and raw data collection. VTC Valdez will have an output printer connected to a communications processor. The processor will be connected, via a modem, to the existing VHF-FM communications system. Figure 5 illustrates the concept.

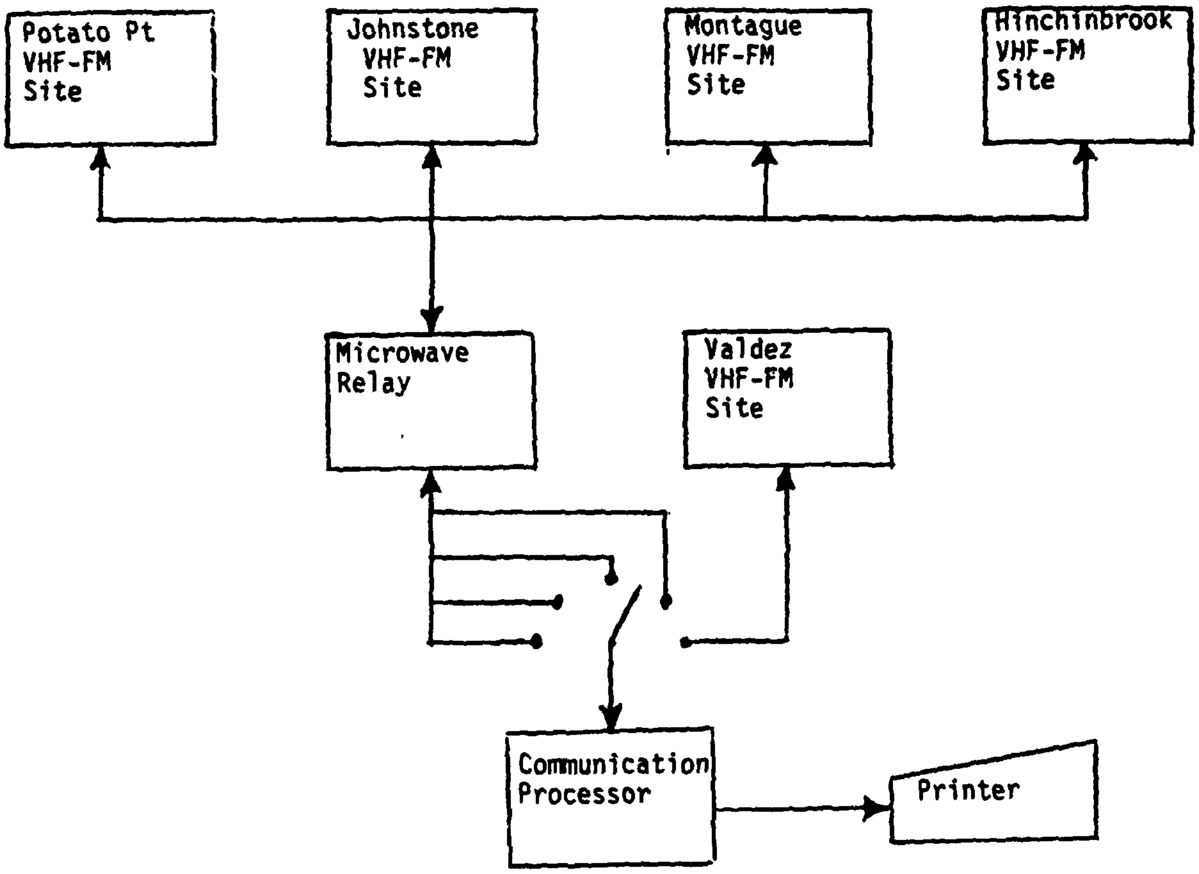
Any vessel participating in the monitoring system would carry a communications processor which would be interfaced to either a Loran-C receiver or some other position determining device. The shipboard communications processor would also be connected, via a modem, to a VHF-FM radio. The processor would obtain either Loran-C time difference or latitude/longitude information from the position determining device and transmit the data via radio when polled. The VTC communications processor would poll the shipboard equipment at regular intervals. The shipboard equipment would respond to each poll by sending the ship's current position as determined by the device to which it was connected. The raw position data, along with the ship's identification would be time annotated and printed out at the VTC so that the watchstander could manually plot the position on a chart.

4.0 ANALYSIS OF IMPLEMENTATION

A number of alternatives are available for implementing the communications subsystem of the proposed position monitoring system. This section discusses some of the alternatives that were considered. This analysis was performed in the context of the conceptual system that is described in Section 3.4. The Transportation Systems Center (TSC), Cambridge, MA assisted in the analysis by providing information on modulation techniques, message structure, acquisition techniques and polling techniques.

4.1 Modulation

Five methods of modulation were considered:



VTS VALDEZ EQUIPMENT

SHIPBOARD EQUIPMENT

FIGURE 5 SYSTEM CONCEPT

(a) Binary Non-Coherent Frequency Shift Keying (FSK)
(b) Binary Coherent Phase Shift Keying (PSK)
(c) Binary Differential Coherent Phase Shift Keying (DPSK)
(d) Quaternary Coherent Phase Shift Keying (QPSK)
(e) Quaternary Differentially Coherent Phase Shift Keying (QDPSK)

Three criteria were considered in the evaluation of these modulation methods.

4.1.1 Bit Error Probabilities

This criterion relates to the theoretical number of errors one can expect to observe in digital messages as a result of the radio signal that carries them. The message errors are expressed in terms of error bits per total number of bits transmitted. The comparison between modulation techniques is achieved by tabulating the theoretical signal-to-noise ratio (SNR) required to yield a nominal value of one bit error per ten thousand (10^5) bits transmitted. This implies that the modulation technique which requires the lowest SNR for a given bit error probability is most efficient. The following list tabulates the five modulation techniques in descending order. Minimum SNR required to achieve a bit error probability of one error per 10^5 bits:

(a) PSK - 9.6 dB
(b) DPSK - 10.3 dB
(c) QPSK - 12.6 dB
(d) FSK - 13.3 dB
(e) QDPSK - 14.9 dB

4.1.2 Performance in a Fading Media

Fading is caused by the cancellation effect of receiving a radio signal via two or more paths. One path will always be a direct path between the transmitting antenna and the receiving antenna. Other paths will be developed as the radio signal bounces off such masses as water, land areas, bridges, other man made structures and the atmosphere. All the phase shift keying techniques, i.e., PSK, DPSK, QPSK, QDPSK, are more susceptible than FSK to interference due to the fading and phase shifting caused by this multipath phenomenon. Also, QPSK and QDPSK are more susceptible to interference than PSK and DPSK.

4.1.3 Complexity of Implementation

The issue of complexity of implementation is a central issue in the analysis of modulation techniques because the final selection is first constrained by the equipment available. Preference should be shown to that technique which involves the least amount of equipment modification. A basic analysis can be made based on receiver designs which involve three methods of modulation detection: (a) coherent detection, (b) differential detection and (c) non-coherent detection.

Coherent detection is employed with the PSK and QPSK modulation techniques. It is accomplished by comparing the received signal to a reference signal that is generated in the receiver. This method of operation would require that some feature be added to the existing VHF-FM equipment to generate the reference signal. This type of equipment modification is estimated to be more complex to implement than modifications discussed below.

Differential detection is employed with DPSK and DQPSK modulation techniques. It is accomplished by comparing a received bit of information to the bit that arrived just before it. This implementation requires that some delay feature be added to the existing VHF-FM receiver to allow the comparison to take place. Of the modifications considered, this is estimated to be the second most complex technique to implement.

Non-coherent detection is employed with FSK and can be accomplished without modifying the existing VHF-FM equipment if the modulation is implemented in the audio baseband. Detection is accomplished in the existing receiver discriminator circuitry. Further conversion to digital baseband signal can be performed on the receiver audio output using an off-the-shelf modem. Operating on the receiver audio output is desirable, because it permits the use of either an existing microwave link or existing telephone lines to relay the data between remotely located radio equipment and any display/processing system without requiring additional modification to the relay link.

4.1.4 Conclusion

FSK modulation was selected for implementation because in two of the three areas of evaluation it was found to be more applicable to available VTS equipment. It is definitely the best choice based on the detection criteria since the existing VHF-FM equipment can be used without modification. Furthermore, all processing to recover a digital message in its original form can be accomplished by demodulating the audio signal after it is output from the VHF-FM receiver. Hence, the microwave relay links presently employed at Valdez can be used without modification. In addition, FSK modulation is the least susecptible to fading of any other modulation techniques considered.

4.2 Message Structure

Two criteria were evaluated:

(a) Data Encoding
(b) Synchronization

4.2.1 Data Encoding

In a binary transmission system such as the one envisioned for this communications link, the choices for a binary code include either a character oriented approach or a straight bit oriented approach. Character oriented codes such as Baudot Code, Binary Coded Decimal (BCD) and American Standard Code for Information Interchange (ASCII) use a fixed number of bits to represent a particular set of alpha-numeric characters. For instance, BCD is a four bit code that is used to represent the numbers 0 thru 9. It is an accepted code which is commonly used, but it can be somewhat inefficient when four data bits represent ten separate characters instead of the sixteen characters it is possible to represent. For this application, Baudot and ASCII are also inefficient because these codes can accommodate a wider variety of characters than is needed. However, using a standard code can make implementation easier. There are many equipments on the market that accommodate ASCII, particularly in the computer world.

Bit oriented codes are probably more efficient in terms of deriving the greatest amount of information using the least number of bits. This is because information can be coded as a single value rather than a character at a time. For example, the binary (bit oriented) representation of 9999 takes fourteen data bits. It would take sixteen bits to represent the number in BCD and thirty-two data bits to represent the number in ASCII. Two major drawbacks in implementing a bit oriented code are that it must be designed from the ground up.

4.2.2 Synchronization

The ability to obtain information from a bit pattern, as received in a digital message, depends on how well the receiving equipment can be synchronized with the bit pattern. The equipment must recognize both the beginning and end of each message and the time of occurence of each bit in the message. Two transmission techniques that are used to provide the necessary synchronization are synchronous transmission and asynchronous transmission. Synchronous transmissions allow the transmission of blocks of bits by establishing synchronization at the beginning of the blocks. This technique usually allows more information to be passed for a given data rate than asynchronous transmission. Asynchronous transmission can be associated with character oriented coding. This technique makes use of additional data bits placed at the beginning and end of each transmitted character. The extra bits indicate to the receiving equipment when the start and end of a character occurs. The advantage of the asynchronous technique is that it is easily implemented when using common coding schemes such as the ASCII code.

4.2.3 Conclusion

The basic criteria for selecting a message structure was to select a structure that was effective and easy to implement. The selection was influenced more by compatibility with existing hardware than by the technical properties of either the coding schemes or the synchronization schemes.

The ASCII coding scheme was selected because it was compatible with presently available hardware, both computers and terminals. In addition, a modestly priced electronics component is readily available that automatically generates the start and stop bits to allow for asynchronous data transmission. This large scale integrated circuit component is called a Universal Asynchronous Receive/Transit (UART) chip. It greatly simplifies the generation of the digital message and eliminates the need for any software overhead to encode and decode the bit patterns. Its use will greatly reduce the cost of implementing the shipboard equipment.

4.3 Polling Techniques

Selective calling, or polling, must be incorporated in the position monitoring system in order to maintain control of the communications link. Each vessel being monitored can be interrogated discretely, thus reducing the risk of interference by random transmissions from other vessels. The polling process involves acquisition and information transfer (polling).

4.3.1 Acquisition

The process of acquisition requires that the identity of all participating vessels be obtained so that they can be regularly polled to obtain updated position information. Four existing acquisition techniques were investigated: (a) acquisition by voice, (b) guard zone plus voice, (c) all-call interrogations and (d) acquisition by random squitter.

Acquisition by voice is a simple, and straight forward technique whereby a vessel calls a VTC to report his presence. The VTC watchstander then either adds the vessel's identification to a polling list or assigns the vessel a temporary identification for polling purposes. The success of this technique depends on a vessel making a timely report when it arrives in a VTS area.

Guard zone acquisition allows for automatic acquisition of a vessel. This technique is based on the establishment of a guard zone at all entrances into a VTS service area. A vessel transiting through the zone prior to entering a VTS area either broadcasts a unique message or answers a unique poll to become included in a polling sequence. This system requires that each vessel possess some type of equipment to recognize when it is in the guard zone so that it can transmit the acquisition signal.

All-call interrogations are commonly used in air traffic control to automatically acquire the identity of aircraft entering a radar surveillance area. The radar signal is used to interrogate a transponder on the aircraft that replies with the aircraft's identification. Normal radar operations give the aircraft's position. The radar application of this technique is not applicable to the vessel monitoring problem because the monitoring is to be carried out outside of radar coverage. However, the all-call concept is viable if a vessel has equipment that carries out the function of the aircraft transponder.

Squitter refers to a signal that is transmitted infrequently and at random times. This technique requires that a vessel transmit a squitter signal containing its identity. The shore station constantly listens for squitter signals, obtains a vessel's identification and adds the identification to the polling list.

4.3.2 Information Transfer

The information transfer process is the actual polling process. The following polling schemes were investigated: (a) random access, (b) hub-type, (c) roll call, (d) time ordered and (e) assigned time slot.

Random access is not a true polling technique although it was evaluated as one in this effort. It can be employed where message traffic is infrequent, and few units are transmitting information. This technique allows a station to transmit at will when it has data to be passed. A modification of this technique employs a timing scheme in which the transmissions are made based on a timed schedule rather than in a random fashion. Both methods can be used in cases where data is not transmitted too frequently and where usage of the communications channel for other communications is low. It is not clear that such conditions exist is the VTS environment.

Hub-type polling is used in computer networks. This technique is used to reduce the amount of time taken to poll all terminals in a computer communications network. In practice, the most distant terminal is polled first. When the most distant terminal replies, it includes in its message the address of the next most distant terminal along with a "go ahead" bit signal. When the next most distant terminal detects the "go ahead" signal, it transmits; this process is continued until all terminals have transmitted. Hub polling eliminates the need for the computer to poll each terminal seperately, and, thus, reduces the polling time. The application of hub-type polling to position monitoring communications appears to be impractical because of the intelligence required of each piece of shipboard equipment to know who to address in the "go-ahead" signal.

In roll-call polling, a central station polls each remote station in sequence. A reply is expected from each remote station immediately after it is polled. The central station has complete control over the polling station. This technique appears to be applicable to the position monitoring communications requirements.

Time ordered polling requires that the responding units be separated by enough distance and that the reply messages be short enough so that the messages arrive at the central station without overlapping. It is anticipated that these necessary conditions would not always exist in a VTS environment to allow time ordered polling to be used successfully.

Assigned time slot polling requires only one interrogation from a central station to get replies from all terminals. To accomplish this, each terminal is assigned a unique time slot in which to reply after receiving a polling signal. This technique reduces the amount of time needed to poll all terminal by eliminating the need to poll each terminals independently. It also could make the reply messages shorter because the unique time slot can be used to uniquely identify each terminal; thus, eliminating the need to include identification in the reply message. In a VTS scenario, assigned time slot polling could be implemented by assigning each vessel a time slot upon checking into a VTS area. The time slot could be manually entered into the shipboard equipment and could be used for the entire time the vessel was in the system. When a ship using a particular time slot departed the VTS area, the time slot could be reassigned to another ship.

4.3.3 Conclusion

In order to achieve a degree of automatic operation, those acquisition and polling techniques that require either voice contact or manual equipment adjustments were not selected. Instead, a modified version of the all-call acquisition technique and the roll-call polling technique was selected. Using the all-call acquisition technique allows for automatic acquisition of vessels as they enter a VTS area. Roll-call polling allows a great amount of flexibility in information gathering by providing the capability to address ships individually. This approach offers the option of polling some ships more often than others and to re-poll a ship if its reply message is garbled. It is anticipated that the combination of all-call acquisition and roll-call polling will allow completely automatic communications.

4.4 Bit Rate

Bit rate refers to the speed with which the individual bits of a digital message are transmitted. There are many standard bit rates that can be used on the VHF-FM communications link chosen for position monitoring. They range from 110 bits per second (bps) to 4800 bps. However, as the speed of transmission increases, so does the rate at which errors occur. Previous experience with a similar communications link showed that a bit rate of 300 bps gave excellent results. However, increasing the bit rate allows the transmission of the same amount of data in a shorter span of time. Therefore, a bit rate of 1200 bps was selected. This transmission speed will provide low error rates and allow the transmission of data four times faster than 300 bps, thus reducing on-air time. In addition, 1200 bps is a standard bit rate which means it can be implemented using existing components.

4.5 Signaling Tones

The selection of binary non-coherent frequency shift keying (FSK) as a modulation technique provided the opportunity to modulate the VHF-FM transmitter with two audio tones. The tones can be generated external to the transmitter and input at the transmitter microphone input connection. This minimizes the amount of modification required in the transmitter. Likewise, demodulation can be accomplished external to the VHF-FM receiver by operating on the audio signal as it appears at the receiver audio output. This technique minimizes the amount of modification required in the receiver. Both transmitter modulation and receiver demodulation can be accomplished using a commercially available MODEM.

The principal operating characteristics of a MODEM are the frequency of its signaling tones and the range of bit rates over which it operates. Common sets of characteristics are identified by name and/or number. The signaling characteristics chosen for the communication link is the Bell 202 characteristic. The two signaling frequencies are 1200Hz and 2200Hz. MODEMS built around this characteristic provide proven performance on telephone systems possessing the same 300Hz to 3000Hz baseband input as the existing VHF-FM transmitters and receivers.

4.6 Carrier Deviation

Transmitters used in the 156 to 174 MH_z band are designed to limit the amount of carrier deviation to +/- 5kHz for a total of 10kHz output bandwidth. The transmitter, however, has a nominal output bandwidth of 15kHz. Modulating signals can be of sufficient amplitude to cause the transmitter to generate sideband frequencies that are not transmitted because they fall outside the 15kHz bandwidth. This causes the transmitted signal to be distorted. The distortion is not noticable when carrying out voice communications because the human ear compensates for it. However, similar levels of distortion may not be tolerable in a machine controlled communications link and large numbers of message error could occur. Therefore, it is advisable to take steps to minimize distortion by controlling the amount of carrier deviation. This can be done by adjusting the output level of the MODEM.

Carson's Rule provides a rule of thumb for calculating allowable deviation levels. The rule relates deviation and modulating frequency to bandwidth in the following expression:

$$B = 2(f_d + f_m)$$

where: B = Bandwidth
f_d = Frequency Deviation
f_m = Modulating Frequency

The above expression defines the bandwidth required to provide enough power in the transmitted spectrum (98 percent) so that modulation can be recovered at a receiver without appreciable distortion. In this case, the bandwidth is set at 15kHz and the frequencies of modulation are set at 1.2kHz and 2.2kHz. Therefore, by transposing the expression to solve for f_d, the theoretical allowable value of f_d is as follows:

(a) at f_m = 1.2kHz: f_d = 6.3kHz
(b) at f_m = 2.2kHz: f_d = 5.3kHz

Since the maximum allowable frequency deviation is 5kHz, the above calculations show that the modulating signals can be adjusted to an amplitude that provides maximum allowable frequency deviation without causing distortion in the recovered signal. However, operating at maximum allowable limits is not practical because distortion could also be caused by existing circuitry which prohibits exceding the $5kH_z$ limit. Such distortion could occur as a result of equipment adjustment error. Therefore, it is recommended that the maximum deviation be limited to a nominal 4kHz to avoid the possibility of unknowingly exceeding the 5kHz deviation level and, thereby, causing distortion in the transmitted signal.

4.7 Summary of Technical Characteristics

As a result of the analysis, the following technical characteristics were selected.

4.7.1 Operating Frequency

The proposed communications link will occupy one of the established channels in the maritime mobile band (156 to 174 megahertz). (Refer to Sect. 4.1)

4.7.2 Modulation

Modulation will be accomplished using a binary non-coherent frequency shift keying (FSK) technique in which two audio tones will be generated to provide the modulation. The modulating tones will conform to the Bell 202 data transmission characteristic. A mark, or binary one, will be represented by a 1200Hz tone, and a space, or binary zero, will be represented by a 2200Hz tone. The amplitude of the modulating signal should not exceed a level that would cause more than 4kHz deviation of the transmitted carrier frequency. (Refer to Sect. 4.2, 4.6 and 4.7)

4.7.3 Data Code

The American Standard Code for Information Exchange (ASCII) will be used. The specific code will be ten level ASCII, consisting of one start bit, seven data bits, one parity bit and one stop bit. (Refer to Sect. 4.7)

4.7.4 Bit Rate

The bit rate will be 1200 bits per second (bps). (Refer to Sect. 4.3)

5.0 DESCRIPTION OF AN OPERATIONAL SYSTEM

An experimental Loran-C position monitoring system called a Polled Loran-C Display System (PLDS) has been implemented. It employs a communication link possessing the technical characteristics summarized in Sect. 4.7. Both the protocol governing link operation and the content and format of the messages passed in the link were selected based on a best estimate of the operational needs to be served. This section will describe the existing PLDS communications concept.

5.1 Polled Loran-C Display System (PLDS) Communication

PLDS makes use of the all-call acquisition technique and the roll-call polling technique discussed in Sect. 4.3. Communications are carried out on a five minute cycle. This cycle begins with an all-call broadcast which invites any ship not being polled to send its identification so that it can be added to the polling list. Once on the polling list, a ship is discretely polled at a rate set by the PLDS operator. The polling rate can vary among ships on the polling list. However, the rate can never be faster than the time required to assure that each ship's equipment could receive and reply to a polling message. This practical limit is approximately two seconds.

5.1.1 Message Format

PLDS communications are carried out using fixed length, fixed format messages. Each message contains thirty three characters; each character is represented by a ten bit ASCII code for a total of three hundred thirty bits per message. Although the characters are transmitted in a continuous string, the characters are grouped into eight fields. The fields are named: (a) Preamble, (b) Destination Identification, (c) Origin Identification, (d) Command Word, (e) Data Block A, (f) Data Block B, (g) Check Sum and (h) End Code. Figure 6 illustrates the message format.

5.1.1.1 Preamble

The preamble is a three character field consisting of three less-than (<) signs. The preamble characters are used to identify the beginning of each message to either the monitor site computer or the ship-board equipment control logic. The preamble is fixed and never changes.

5.1.1.2 Destination Identification

The destination identification is the identification of the station for which the message is intended. The destination identification generally consists of five numeric characters arranged in order of significance so that the least significant character is the right-most character of the field. All leading zeros are represented by the ASCII code for a space. The non-numeric exception for the destination identification is the all-call broadcast which causes the characters "COCO2" to appear in the field.

5.1.1.3 Origin Identification

The origin identification is the identification of the station transmitting the message. This five character field will always consist of numeric characters arranged in order of significance so that the least significant character is the right-most character in the field. All leading zeros are represented by the ASCII code for a space.

5.1.1.4 Command Word

The command word is a three character, alphabetic field. This field is used to command the shipboard equipment to perform certain functions. At present the following command words are used:

(a) ENT - Used in the all-call broadcast to invite entry into the system
(b) RPT - A request for position data
(c) QSY - The command to change to a specified radio channel
(d) XNT - A signal that the ship will not be polled again.

5.1.1.5 Data Block A

Data Block A consists of seven alpha-numeric characters which can be

GENERAL MESSAGE FORMAT

PREAMBLE	DESTINATION ID	ORIGIN ID	COMMAND WORD	DATA A	DATA B	CHECK SUM	END CODE
3 char.	5 char.	5 char.	3 char	7 char.	7 char.	2 char	1 char.

MESSAGE TYPE	VTS MESSAGE	SHIP MESSAGE
1. Broadcast Message	<<<CQCQ?99999ENT*__________CS>	<<<9999912345ENT34567808765430CS>
2. Polling Message	<<<1234599999RPT*__________CS>	<<<9999912345RPT34568108765390CS>
3. Termination Message	<<<1234599999XNT*__________CS>	No Reply
4. Change Channel	<<<1234599999QSY_01*__________CS>	<<<9999912345QSY_01__________CS>

Notes: VTS ID is 99999
Ship ID is 12345
* These blanks are represented by the ASCII code for a space.
The transmitter is keyed approximately 150 milliseconds before modulation begins and remains keyed 30 milliseconds after modulation ends.

SIGNALLING FORMAT

SIGNALLING TONES

BELL 202
Mark = 1200 Hz
Space = 2200 Hz

SIGNALLING CODE

10 Bit ASCII
7 Bits for Data
1 ea. Bit for Start, Stop, Parity

BIT RATE

1200 Bits/second

Figure 6 PLDS MESSAGE FORMATS

used to convey information. In response to the command word RPT, the shipboard equipment transmits a Loran-C time difference reading in this data block. The characters are arranged in order of significance so that the least significant character is the right-most character of the field, all hyphens, slashes and decimal points are not included in the field. Leading zeros are represented by the ASCII code for a space. In response to the command word OSY, the data transmitted corresponds to a channel on a radio set. It consists of two numeric characters which are positioned so that the left-most character in the field is a space, and the two characters follow the space with the most significant character left justified. All other characters are spaces. In addition, in an all-call broadcast, transmitted from the base station (CQCQ?), all seven transmitted characters are represented by ASCII code for a space.

5.1.1.6 Data Block B

Data Block B consists of seven numeric characters which can be used to convey information. In response to the command word RPT, the shipboard equipment transmits a Loran-C time difference reading in this data block. The characters are arranged in order of signifance so that the least significant character is the right-most character of the field. All hyphens, slashes and decimal points are not included in the field. When an all-call broadcast is made, the characters in this field are represented by the ASCII code for a space. Also, in a poll using a OSY command word, the characters in this field are represented by the ASCII code for space.

5.1.1.7 Check Sum

The check sum is used to detect transmission errors, a check sum value is generated for each message by summing the bytes representing all the characters of the digital message up to, but not including, the check sum. The summing operation is performed on the seven data bits only. The addition is performed without carry. The number is calculated at the transmitting station and included in the digital message. It is also calculated at the receiving station upon receipt of the message. If the check sum calculated at the receiving station matches the check sum contained in the digital message, it is assumed that no transmission errors have occured.

The check sum field contains two ASCII characters. However, due to the manner in which the check sum is calculated, the range of values appearing in either of the character locations is limited to the hexidecimal values 0 through F.

5.1.1.8 End Code

The end code character is a greater than (>) sign. It appears at the end of each message.

5.2 PLDS Communication Protocol

All communications are controlled by the PLDS computer located at a

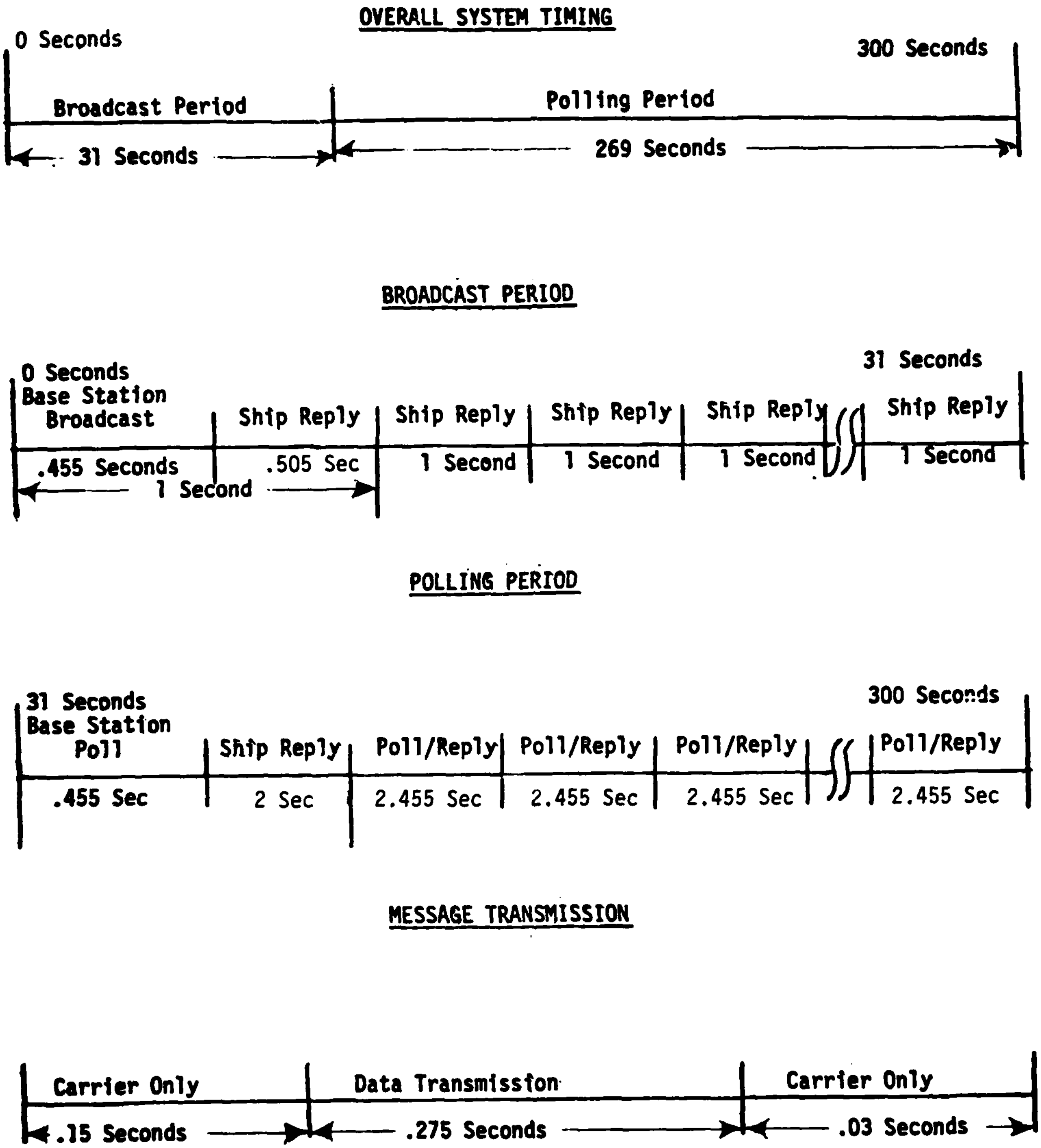


FIGURE 7 SYSTEM TIMING

base station and can be thought of as occurring in a five minute cycle. (See Figure 7). Each cycle begins with an all-call broadcast which invites any vessel not being polled to signal its presence in the VTS area. Once vessels are included in the polling list, they are polled at a rate selected by the base station operator. Each vessel could be polled at a different rate if so desired.

5.2.1 All-Call Broadcast

The base station broadcasts the all-call signal once every five minutes. This broadcast is identified by the characters "COCO?" in the destination identification field, the characters "99999" in the origin identification field and the characters "ENT" in the command word field. Ships entering the VTS area monitor the communication frequency for the all-call broadcast. When the broadcast occurs, the shipboard equipment starts a timer that counts the seconds from the end of the broadcast. The shipboard equipment also activates a random number generator that generates a random integer number from 0 to 29. The equipment delays the transmission of a reply to the all-call broadcast in the number of seconds after the broadcast ends by the number of seconds corresponding to the randomly generated integer number. When the random number equals 0, the shipboard equipment transmission is delayed 0.4 second after the end of the all-call broadcast. Each ship's reply includes the characters "99999", as the destination identification, own ship's identification as the origin identification, the command word ENT and its Loran-C position coordinates in DATA BLOCK A and DATA BLOCK B. The shipboard equipment continues to answer each successive broadcast until it is polled.

5.2.2 Polling Message

When the base station receives an error free message from a ship in reply to an all-call broadcast, it adds the contents of the origin identification field of the message to its polling list. This enters the ship into the polling scheme. During the four minutes and twenty-nine seconds between all-call broadcasts, the PLDS computer polls each ship at a specified rate. Upon receiving an error free polling message from the base station, the shipboard unit must complete its reply within approximately 2 seconds of receipt of the last character of the message.

The base station's polling message contains the ship's identification in the destination identification field, the base station's identification in the origin identification field, the characters RPT in the command word field and space characters in the DATA BLOCK A and DATA BLOCK B fields. The ship's reply message will contain the base station's identification in the destination field, the ship's identification in the origin field and the ship's Loran - C position coordinates in the DATA BLOCK A and DATA BLOCK B fields.

5.2.3 Change Channel Message

The change channel message is initiated from the base station. The message includes the identification of the ship in the destination identification field, the identification of the monitoring station in the origin identification, the characters QSY in the command word and a two digit channel number in DATA BLOCK A. DATA BLOCK B contains all space characters. The two digit channel number pertains to a channel of a radio set rather than to a particular frequency. The ship's reply message will contain the base station's identification in the destination identification field, the ship's identification in the origin identification field, the characters QSY in the command word field and the two digit number of the new channel in the DATA BLOCK A. The DATA BLOCK B will contain all space characters. The shipboard unit must complete its reply within approximately 2 seconds of receipt of the last character of the base station's message.

5.2.4 Termination Message

The termination message is used to signal a ship operator to turn off his equipment. The message is initiated by the base station operator. The termination message contains the ship's identification in the destination identification field, the base station's identification in the origin identification field and the characters XNT in the command word. DATA BLOCK A and DATA BLOCK B contain all ASCII space characters. There is no reply to an XNT message. Instead, an alarm is initiated on the shipboard unit that tells the shipboard operator to turn his unit off.

5.3 Message Error Handling

PLDS only operates on error-free digital messages. When messages containing errors are received, they are ignored. No additional polling is attempted; the next poll occurs when the ship's identification appears in regular rotation in the polling list.

6.0 SUMMARY AND RECOMMENDATIONS

The position monitoring system requirements as discussed in this report can be met with the existing PLDS system. Implementation of the PLDS communications for VTS Valdez is recommended. Appendix A lists the critical parameters of the communications subsystem required at VTS Valdez. The remainder of this section will discuss other modifications that could easily be made to the communications protocol to improve its efficency.

6.1 Communication Reliability

There are four major factors that will affect the reliability of position monitoring communications at Valdez. They are:

(a) The reliability of the micro-wave relay links.

(b) The interference caused by both voice communications on the PLDS frequency and cross talk and muting override in the communications consoles in the VTS operations center.

(c) The quality of radio equipment used by vessels participating in the system.

(d) The effects of propagation path loss as a function of the distance between a ship's antenna and the VTS communications antenna.

Item (a) and (b) above are considered to be outside the scope of this paper because they are part of the day-to-day operations of VTS Valdez. Items (c) and (d) will be discussed because they can, if deemed necessary, be addressed in regulations.

6.1.1 Shipboard Radio Equipment

The quality of shipboard equipment has a greater impact on digital communication than on voice communications. In general, this is because the human ear either cannot perceive small distortions caused in the transmission of voice or is able to compensate for it. On the other hand, the circuits that accomplish digital communications cannot tolerate the same levels of distortion. Therefore, both the original quality of equipment placed aboard a ship and the quality of the equipment at the time of use can impact on the reliability of digital communications.

The proposed communications system makes use of two signaling tones in the voice band. The concept of operations is that the tones be input to a transmitter in the same manner as voice is input, and that they be converted to a digital form after being output by the audio section of a receiver. This implies that if some minimum level of transmitter and receiver performance was established, then some minimum expected level of communications link performance could be expected.

An accepted radio equipment standard is set by the Electronic Industries Association (EIA). Although compliance with EIA standards is not mandatory, most U.S. manufacturers produce equipment that either equals or exceeds the EIA standard. EIA Standard RS-204-A contains the standards for Frequency Modulation (FM) receivers in the maritime mobile band. This document specifies a minimum level of performance for the salient operating characteristics of an FM receiver. In a like manner, EIA Standard RS-152-B contains the standards for transmitters in the maritime mobile band. It is recommended that reference to these EIA standards be included in any system specifications.

6.1.2 The Effects of Propagation Path Loss

Path loss is the attenuation of radio signal power as the signal travels through the atmosphere. The minimum level of transmitter power required to operate over the desired position monitoring system operating area must be specified. This specification can be obtained by calculating the radiated transmitter power output necessary to meet the minimum receiver input requirements at the maximum operating range.

The maximum operating distance is the distance from Johnstone Pt. radio site to a point in the traffic lanes abeam of the southern tip of Bligh Island. The distance is twenty three nautical miles. The minimum receiver requirement was selected as .35 micro volts sensitivity to produce an EIA 12 dB SINAD audio output. By way of comparison, the same requirement was calculated for Montague Pk which is a distance of thirty two nautical miles.

The basic expression is:

$P_r = P_t + G_1 + G_2 - A$

P_r = Power at Receiver
P_t = Power at Transmitter
G_1, G_2 = Antenna Gain
A = Path Loss

Conditions:

(a) Path Loss (A) from graph in Figure 8.

(1) Johnstone Point (23 n.m.) - 145 dB
(2) Montague Peak (32 n.m.) - 154 dB

(b) Minimum Required Power at the Receiver (P_r)

(1) .35 microvolts across 50 OHM impedance - (-) 146.1 dB

(c) Antenna Gain (G_1, G_2)

(1) Shipboard - OdB
(2) Receiver site - OdB

Transposing the basic expression to:

$P_t = P_r - G_1 - G_2 + A$

The required minimum transmitter power is:

(a) Johnstone Point - (-) 1.1 dB or 1.3 Watts
(b) Montague Peak - 7.9 dB or 6.2 Watts

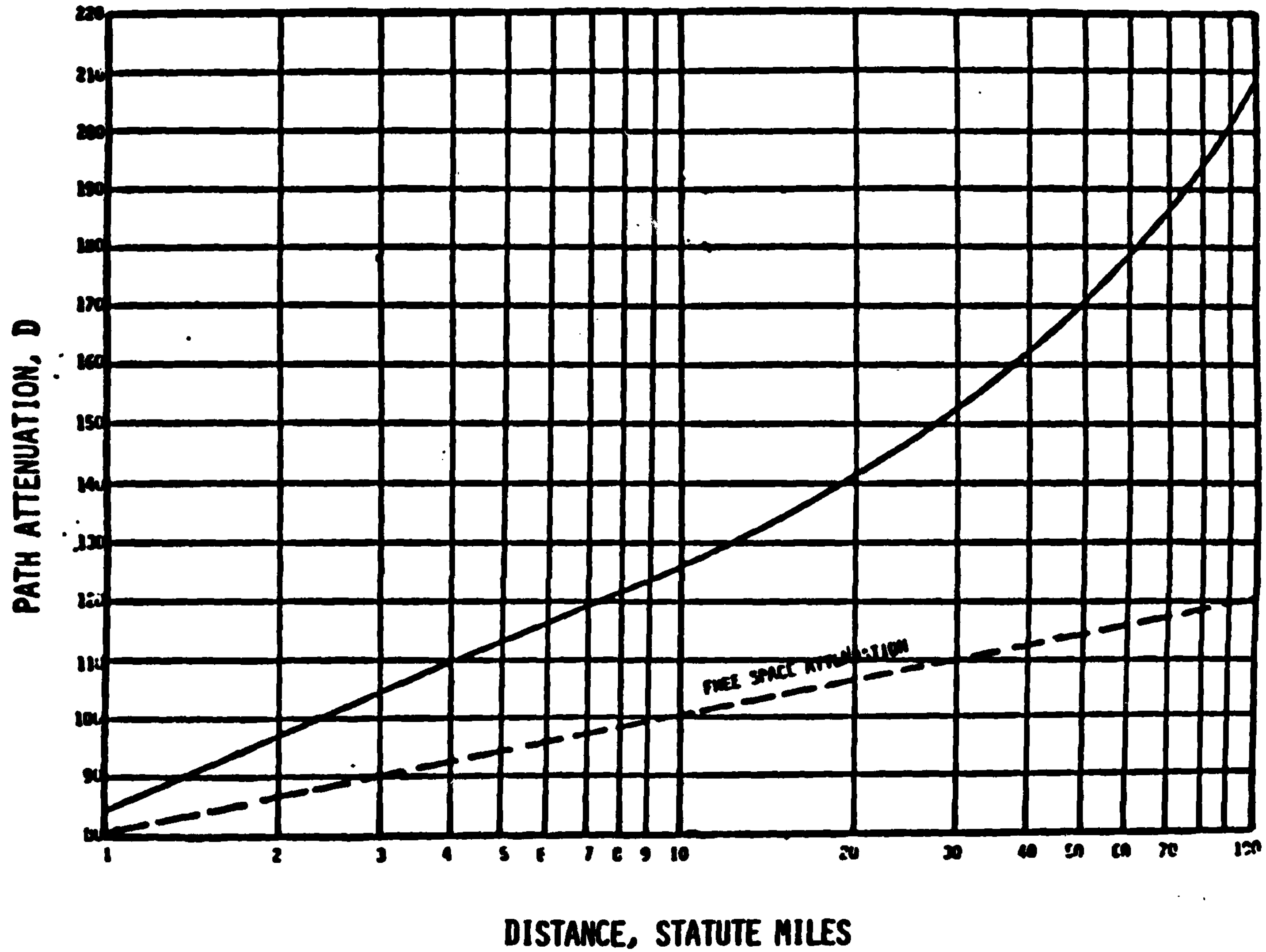
These calculations indicate minimum radiated power requirements. Some margin of safety should be added to the values to insure satisfactory operation. In the absence of any further data to indicate an acceptable level of output, it is recommended that the required power output from either a shipboard transmitter or a base station transmitter be set a 25 Watts (14 dBW).

6.2 Variation of the Operating Concept

The communications link implemented in the experimental position monitoring system, PLDS, has been tested and found to be acceptable. There are, however, some variations to the concept that might be applied to the link to make it more efficient for use at Valdez, Ak. These variations involve modifying the acquisition/polling technique and modifying the message formats. Each variation effects the way the final system is implemented. Therefore, they cannot be arbitrarily tried and discarded without some cost impact.

6.2.1 Changes to the Acquisition/Polling Technique

The acquisition/polling technique was selected to provide for automatic operation. The all-call broadcast occupies thirty-one seconds



PATH ATTENUATION VS. DISTANCE OVER SEA WATER
Derived from NDRC Propagation Curves
Bell Telephone Laboratories, Inc. Report 9966-6C

FIGURE 8 SIGNAL ATTENUATION GRAPH

every five minutes even if there are no ships to acquire. Each polling message takes approximately .45 seconds to transmit, and the reply can begin up to 1.55 seconds after the poll. This makes the possible total time occupied by one polling message and its reply to be approximately 2.45 seconds. Some easily implemented changes could be made to decrease these times, thus reducing on-air time and increasing the amount of data that could be handled.

The operating environment at Valdez suggests that an acquisition phase is not needed. All ships of interest report their estimated time of arrival at least thirty minutes prior to entry into the system. Under this mode of operation, ship's identification number could be passed to the VTC when the ship reports its estimated time of arrival, and the VTC controller could enter the number directly into a polling list by some manual means. This would eliminate thirty-one seconds of potential dead air time allocated to the all-call broadcast every five minutes, and result in a conservation of approximately 2.5 hours of wasted transmit time every day.

A change from the presently used roll-call polling technique to an assigned time slot polling technique could also reduce the on-air time. The present system utilizes approximately 0.45 seconds for polling, up to approximately 1.55 seconds delay before they reply message arrives and 0.45 seconds for the reply message itself. This makes a total of 2.45 seconds of on-air time. In a worst case situation where eighteen ships were being monitored, it would take a maximum of 44.1 seconds to poll each ship once and get a reply. By using the assigned time slot polling technique, the on-air time could be reduced by better than one-half. For example, using the same length messages and assuming a 0.55 second guard time between messages, all ships could be polled in 18.5 seconds. Under an assigned time slot polling scheme, each ship could be assigned a time slot when it reports its arrival to the VTC. The shipboard operator could manually enter the time slot indentification into his equipment. One disadvantage of using assigned time slot, however, is that it prevents the transmission of any control information to individual ships as is done by the present PLDS communications link.

6.2.2 Modifying the Message Format

The PLDS messages are fixed format. Each message takes approximately 0.45 seconds to transmit. The polling messages, however, contain a large number of spaces: each space requires a ten bit ASCII code to be transmitted. Therefore, the polling messages could be shortened to the length of the message containing the longest string of meaningful characters. The longest polling message is the change channel (QSY) message which contains twenty meaningful characters. By using twenty characters in the polling message instead of thirty-three, the time required to transmit the message is reduced from approximately 0.45 seconds to approximately 0.35 seconds. If all polling messages were reduced to a fixed length of twenty characters, each poll/reply communication sequence would be 0.10 seconds shorter.

APPENDIX A
RECOMMENDED SUBSYSYSTEM PARAMETERS

A.1 Radio Transmitter and Receiver

Communications will be carried out using the type of radio transmitter and reciever normally used in the maritime mobile band 156 to 174 MHz. This equipment is frequency modulated with a maximum frequency deviation ± 5kHz. The communications link will be established on one of the currently designated channels.

A.2 Signaling Characteristics

Signaling will be accomplished using audio frequency shift keying (AFSK). There will be two signaling tones that conform to the Bell 202 characteristic. 1200 Hz represents a mark or binary one, and 2200 Hz represents a space, or binary 0. The input amplitude of the tones should be adjusted to provide between ± 3.5k Hz and ± 4kHz deviation of the transmitted carrier frequency. This range is an arbitrarily selected range to insure a uniformity of audio signal strength.

A.3 Data Code

Data will be coded using the ten level American Standard Code for Information Interchange (ASCII) code which includes one start bit, seven data bits, one parity bit and one stop bit. Parity will be even. Data will be transmitted at 1200 bits per second (bps).

A.4 Communications Protocol

The communications cycle will be selectable by the VTS operator at either one, two, three or four minutes. During each cycle, the first thirty-one seconds will be allocated to the acquisition broadcast and the remainder of the time will be used for polling. The polling rate will be the same for all vessels being monitored. The presently estimated worst case situation of eighteen ships being tracked at one time can be handled by this system.

A.4.1 All-Call Broadcast

The all-call broadcast is used to acquire the identification numbers of ships entering the VTS service area so that they can be polled. Upon receipt of the broadcast signal, the shipboard equipment will generate a random integer number ranging from 0 to 29; the equipment will also start a timer. When the timer has counted a number of seconds since the end of the broadcast message that is equal to the random number, the shipboard equipment will transmit the ship's identification number and it's position coordinates. The message format is be described in A.5. Timing begins with the receipt of the last character of the broadcast message. When the random number is 0, the shipboard equipment must begin transmitting within 0.4 seconds of the end of the all-call broadcast.

A.4.2 Polling Message

Once a ship's identification number has been acquired via the all-call broadcast, that ship will be polled regularly to obtain position information. The message formats will be described later in this appendix. The shipboard equipment will begin transmitting its reply to a polling message as soon after receipt of the message as possible. Under no circumstances should the transmission of the reply message begin later than 1.0 second after the receipt of the last character of the polling message. The 1.0 second time limit is an arbitrary limit selected to insure the poll/respond communications event will be completed in a reasonable amount of time. It is anticipated that the shipboard equipment can easily respond within this time limit.

A.4.3 Message Error Handling

The position monitoring system will only process error free messages. Any messages with errors will be ignored. When either station receives a message with an error in it, the message will be discarded and no action will be attempted. For the all-call acquisition broadcast, the shipboard unit will not reply to a message which contains an error, and the base station equipment will not add a ship's identification to the polling list when it receives a reply with an error in it. If a shipboard unit replies to an all-call broadcast and is not polled before the next all-call broadcast occurs, the shipboard unit must be able to respond to the next all-call broadcast. For polling messages, the shipboard unit will not respond to a polling message containing an error, and the base station equipment will discard a reply containing an error. When an error free reply is not received as a result of a polling message, the base station equipment will transmit an additional poll after it has polled each ship in its polling list. Upon being entered into the system both by answering an all-call broadcast, and receiving and answering a polling message, a shipboard unit should receive one error free polling message during the period between each all-call broadcast. If two all-call broadcasts occur and a shipboard receiver has not received an error free polling message, the shipboard equipment will automatically answer the third all-call broadcasts.

A.5 Message Format

The general message format is shown in Figure A-1. All messages, both base station originated and ship originated, have the same format and are the same length. Each message contains eight fields. The fields are named: (a) Preamble, (b) Destination Identification, (c) Origin Identification, (d) Command Word, (e) Data Block A, (f) Data Block B, (g) Check sum and (h) End Code. The following is an explanation of each field

A.5.1 Preamble

The preamble marks the beginning of each message. It consists of three less-than signs (<). The preamble characters never change.

GENERAL MESSAGE FORMAT

PREAMBLE 3 char.	DESTINATION ID 5 char.	ORIGIN ID 5 char.	COMMAND WORD 3 char	DATA A 7 char.	DATA B 7 char.	CHECK SUM 2 char	END CODE 1 char.

MESSAGE TYPE	VTS MESSAGE	SHIP MESSAGE
1. Broadcast Message	<<<CQCQ?99999ENT*__________CS>	<<<9999912345ENT34567808765430CS>
2. Polling Message	<<<1234599999RPT*__________CS>	<<<9999912345RPT34568108765390CS>

Notes: VTS ID is 99999
Ship ID is 12345
* These blanks are represented by the ASCII code for a space.
The transmitter is keyed approximately 150 milliseconds before modulation begins and remains keyed 30 milliseconds after modulation ends.

SIGNALLING FORMAT

SIGNALLING TONES

BELL 202
Mark = 1200 Hz
Space = 2200 Hz

SIGNALLING CODE

10 Bit ASCII
7 Bits for Data
1 ea. Bit for Start, Stop, Parity

BIT RATE

1200 Bits/second

FIGURE A-1 RECOMMENDED MESSAGE FORMAT

A.5.2 Destination Identification

This is an alpha-numeric field that identifies the station to which a message is addressed. The characters in the field are oriented in order of significance so that the least significant bit is the right-most character in the field. All leading zeros will represented by the ASCII code for a space. For the most part, the characters in this field will be numeric; the exception occurs in the all-call broadcast in which COCQ? appears in the field. Both shipboard and base station units will include a destination identification in each transmitted message. The base station equipment will obtain the identification numbers via the all-call broadcast. The shipboard unit will obtain the identification number from the origin identification field of either an all-call broadcast or a polling message.

A.5.3 Origin Identification

The origin identification is a five character numeric field that contains the identification of the station transmitting each message. The characters will be oriented in order of significance so that the least significant is right-most in the field. All leading zeros are represented by the ASCII code for space. Each message transmitted will contain an origin identification.

A.5.4 Command Word

This is a three character alphabetic field. The field is used to command the shipboard units to perform certain functions. The shipboard unit will always echo back the command word contained in the polling message to which it is responding. It is recommended that only the command words FNT and RPT be used in Valdez because:

a. The Loran-C printers intented for use at Valdez will not support automatic channel changing.
b. The termination message need not be sent because each ship can be instructed to turn off its equipment when it checks out of the VTS.

A.5.5 Data Block A

Data Block A is a seven character alpha-numeric field. This field will be used by each ship to transmit either the M-X time difference reading from a Loran-C receiver or the ship's position latitude coordinate. In either case, all slashes, hyphens and decimal points will be eliminated from the value before its placed in Data Block A. The characters will be oriented in order of significance so that the least significant character is right-most in the field. All leading zeros will be represented by the ASCII code for space. Either a time difference or a latitude value will be included in each ship's response to either an all-call broadcast or a polling message.

A.5.5.1 Time Difference Value in Data Block A

The time difference value placed in Data Block A will contain the complete time difference value to 0.1 micro-second resolution. This will place six characters in the field. The seventh character, a leading zero, will contain a space.

A.5.5.2 Latitude Values in Data Block A

The presence of a latitude value in Data Block A will be indicated by placing the letter "N" in the left-most character of the field. The remaining six characters will contain the latitude value expressed in one of the two ways: (a) degrees, minutes, seconds or (b) degrees, minutes, tenths of minutes. The following conventions will be used in positioning the latitude value in the remaining six data block characters:

(a) Where Degrees, Minutes, Seconds are used, the value will be entered as follows- DDMMSS. The complete field will be appear as follows- NDDMMSS.
(b) Where Degrees Minutes, Tenths of a minute are used, the value will be right justified in the field as follows - DDMMT. The complete field will appear as follows - N DDMMT. A Space character will seperate the letter N from the latitude value.

A.5.6 Data Block B

Data Block B is a seven character numeric field. This field will be used by each ship to transmit either the M-Y time difference reading from a Loran-C receiver or the ship's position longitude coordinate. In either case, all slashes, hyphens and decimal points will be eliminated from the value before it's placed in the field. The characters will be oriented in order of significance so that the least significant character is right most in the field. All leading zeros will be represented by the ASCII code for space. Either a time difference or a longitude value will be included in each ship's response to either an all-call broadcast or a polling message.

A.5.6.1 Time Difference Value in Data Block B

The time difference value placed in Data Block B will contain the complete time difference value to 0.1 microsecond resolution. This will provide six characters in the field. The seventh character, a leading zero, will contain a space.

A.5.6.2 Longitude Value in Data Block B

The longitude value can be expressed in two ways: (a) Degrees, Minutes, Seconds and (b) Degrees, Minutes, Tenths of a Minute. The following convention will be used in positioning the longitude value in the field:

(a) Where Degrees, Minutes, Seconds are used, the value will appear as follows - DDDMMSS.

(b) Where Degrees, Minutes, Tenths of a minute are used, the value will appear as follows - DDDMMT. The value will be right justified in the field. The left-most character will be a space.

A.5.7 Check Sum

The check sum is used to detect transmission errors. A check sum value is generated by each station transmitting a message and is included in the message. The receiving station also calculates the check sum; if the transmitting station value and the receiving station value match, no transmission errors occurred. The check sum is calculated by summing, without carry, the seven data bits in each character of a message up to, but not including the check sum. The result is a seven bit word which is the check sum value. Taken with an unused sign bit, the word becomes an eight bit word. The eight bit word is divided into two four bit nibbles. Each of the nibbles is placed in the least significant bit positions of one of the two ASCII check sum characters and transmitted.

A.5.8 End Code

The end code character is greater-than (>) sign. It appears at the end of each message.

A.6 Time Characteristic of each Transmission

Each message is thirty-three characters long for a total of three hundred thirty bits. When transmitted at 1200 bits per second, each message takes 0.275 seconds to send. However, in order to insure that the receiving station's radio receiver's squelch circuit is off, the transmitter carrier will be transmitted 0.150 seconds prior to beginning modulation. Also, the carrier will be kept on 0.030 seconds after modulation stops. This means that each transmission will occupy 0.455 seconds of on-air time. Figure A-2 shows the various timing relationships.

A.7 Ship and Shore Station Identification

The five character identification for both ship and shore stations was selected to conform with the requirements of the International Telecommunications Union Radio Regulations concerning selective call numbers assigned in the maritime mobile service. Article 19, Paragraph 25 of the regulations prescribe that ship station selective call numbers consist of five digits. However, operational requirements of the recommended position monitoring system preclude the use of the two numbers 00000 and 99999 as ship station identification numbers. These numbers must be reserved for the shore station identification.

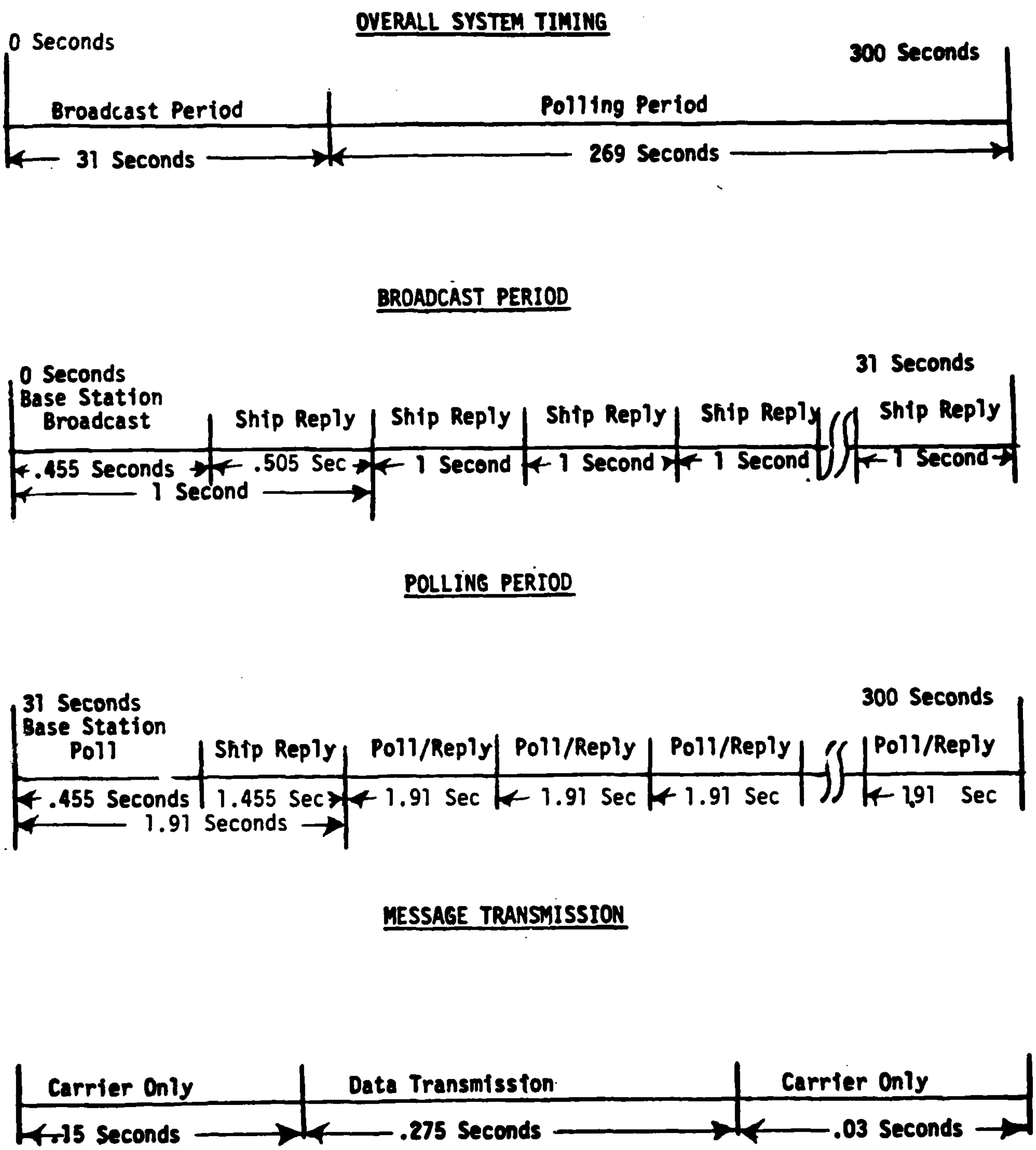


FIGURE A-2 RECOMMENDED SYSTEM TIMING

2.5 References

(a) R&D System Requirements for Valdez Precision Vessel Tracking System dtd December 1977.

(b) "Vessel Traffic Services-What's Next?" LCDR A. R. Whittum, USCG; ION Proceedings, 1 November 1978.

(c) Vessel Traffic Service Prince William Sound Operating Instructions (CGD17-010) dtd July 1977.

(d) Vessel Traffic Service Prince William Sound Traffic Center Manual dtd March 1979.

(1) Taub and Schilling, Principles of Communication Systems, McGraw-Hill, 1971, pp 133.